Paper 11

An analysis of the benefits of 3D pre-stack time migration

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Conventional 3D seismic imaging consists of NMO, DMO, stack and zero-offset time migration. Initially, NMO velocities are only approximate while constant velocity (or v(z) DMO is applied, after which the NMO velocities are refined. This is done because DMO (even though it is applied using only an approximate velocity) removes most of the dip-dependence of the velocity and hence, most of the multivaluedness of the velocities. However, significant difficulties still remain. Multivalued moveout velocities are still present after NMO/DMO due to the approximate velocity fields used in their application. It can also be shown that primary reflections emanating from other than within the plane of velocity analysis generally have shower anomalous velocities and may be mistaken for multiples. The addition of a 3D zero-offset time migration after DMO (often using the same simple velocity field as used for DMO) helps avoid these residual difficulties. The benefits of 3D pre-stack time migration include improved stacking, attenuation of dipping noise, a more accurate velocity field and a better quality final migration.

Constant velocity 3D DMO (and even v(z) DMO to a lesser extent) tends to over-correct the velocity of dipping events. Before DMO the velocity of dipping events is artificially high, but the application of DMO with a simplistic velocity field tends to slow the apparent velocity too much and actually results in a slighter slower velocity than necessary. When dipping and flat events cross, the dipping events will need a slower stacking velocity. Hence the stacking velocity is multivalued and stacking much compromise at least one of these events. Applying 3D pre-stack time migration avoids the possibility of crossing events by migrating them all to their correct reflector location. This significantly simplifies velocity interpretation, avoids the multivalued velocity issue and results in an improved stack.

Primary reflections that have originated out of the plane of recording also cause problems due to their crossline dip component. Conventional production 3D DMO only incorporates the inline (source to receiver azimuthal) component of the DMO correction since the crossline component has only a minor effect and greatly increases the cost (for constant velocity DMO there is no crossline response). This means that production 3D DMO does not compensate for the crossline dip in the presence of a vertically varying velocity. The net effect of this is that out of plane primaries will tend to have a slower velocity than inplane primaries, even though both may appear to have no dip in the inline direction. During interpretation of the stacking velocities, such out of plane primaries may look like multiples and be deliberately attenuated by the stacking process or any multiple attenuation algorithms that are applied. Once again, the application of 3D pre-stack time migration avoids the multivalued stacking velocity problems by migrating any out of plane events to their correct reflector position, simplifies velocity analysis and produces a superior stack.

The 3D pre-stack time migration processing sequence is completed by stacking the migrated gathers and either applying a residual migration or a combination of inverse migration and complete re-migration. Before the gathers are stacked, a conventional style muting pattern is applied. Due to the action of the 3D pre-stack time migration any dipping noise will migrate updip and steepen its dip. Some of this noise will also migrate into the standard muting zone and is therefore removed before stack. Consequently if the stacked data is denigrated such dipping noise cannot be re-introduced. Muting the dipping noise also helps simplify velocity analysis.

As mentioned above, interpreting velocities after 3D pre-stack time migration is greatly simplified. Often somewhat complicated analyses are transformed into more easily interpreted panels, with clearer primary trends. Velocities can be interpreted with more confidence and out of plane primaries do not appear to be multiples. Consequently, it can prove advantageous to attempt multiple suppression (or more aggressive multiple suppression) on the 3D pre-stack time migrated gathers.

The velocity field interpreted from 3D pre-stack time migrated gathers is generally more stable and more closely resembles the true velocities of the medium. Coupling this with the fact that the velocities are naturally interpreted in migrated position, the resulting velocity field is ideal for a high fidelity final zero offset time or depth migration. The 3D pre-stack time migration can be exactly removed after stack if the migration used was either constant or a single velocity function with depth. This inverse migrated dataset is then identical to a conventional stacked dataset except that is has the benefits of the superior stacking and noise attenuation as outlined above. At this pint an improved stacked volume is available as well as a superior migration velocity field which are the ingredients for an excellent final migration with a high fidelity algorithm. The closer resemblance of the interpreted velocities with the true earth velocities also assists with depth conversion

After applying this technique widely to synthetic and real 3D datasets, all of the above benefits can be demonstrated. Synthetic data examples clearly show the theoretical benefits of 3D pre-stack time migration. Real data examples give an indication of the practical extend of improvements.

The addition of an approximate 3D pre-stack time migration to the conventional NMO/DMO sequence has a number of positive benefits and conforms with the application of approximate velocity NMO and simplified velocity DMO. The application of 3D pre-stack time migration can be thought of as a transform. The data is transformed to the migrated gather domain where velocity analysis, noise attenuation and multiple suppression can be easier, and is then inverse transformed after stack using inverse migration. The result is a superior stack and migration velocity field. However, it should be remembered that the pre-stack migration is a time migration. If rapid lateral variations exist the process will not be applicable as the time migration will not be able to migrate the events to their correct location.